Spatial patterns in vegetation response to climate variability in the American Southwest

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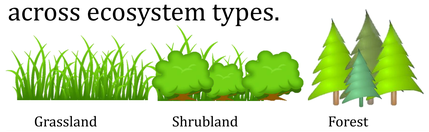
Introduction

Objective:
To generalize plant functional responses to climate variability across ecosystem types.

Changes in climate ⇩ **Changes in plant production**



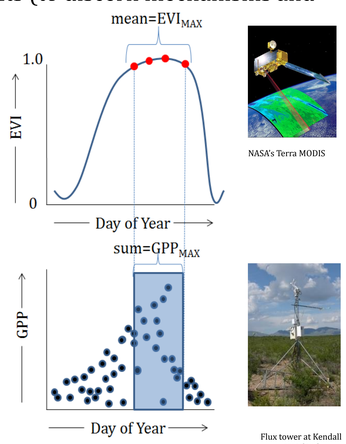
In the Southwest, the early 21st century warm drought is similar to predicted future climate change scenarios for the region (MacDonald, G.M. 2010, *PNAS*). Plant functional responses to climate variability are not currently well-understood and thus the response of aboveground net primary productivity (ANPP) to future climate conditions is highly uncertain.

Coupled Approach

Remote sensing observations (to assess interannual variability) were coupled with *in situ* flux measurements (to discern mechanisms and validate).

Remote Sensing

Vegetation Production: NASA MODIS Enhanced Vegetation Index (**EVI**) served as a proxy for production. EVI_{max} was calculated by smoothing the MOD13Q1 product and then averaging the 4 maximum EVI observations.



NASA's Terra MODIS

Eddy Covariance Flux Towers

Vegetation Production: Gross primary production (GPP) is modeled from the following equation:

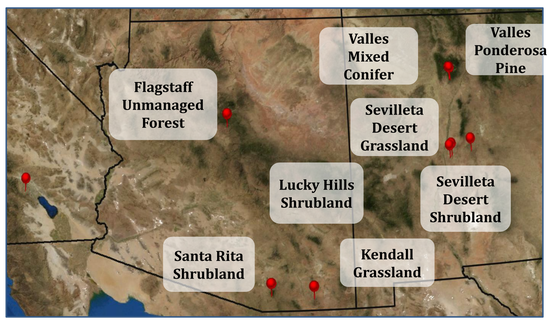
NEE = GPP - R_{eco}

Calculated GPP was daily. For validation of remotely sensed results, daily maximum GPP was summed over the same time period as EVI_{MAX}

Flux tower at Kendall grassland photo by Russell Scott

Sites

Ten Ameriflux sites across Southwest ecosystem types were chosen



3 sites

3 sites

2 sites

Hypotheses

To determine the *relative* importance of climate drivers and legacies in different ecosystem types two hypothesis were derived from Sala et al. (*Phil Trans. Royal Society,* 2012)for grasslands and Williams et al. (*Nature CC,* 2011) for forests.

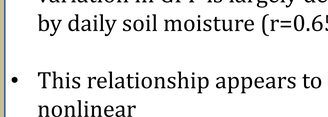
Sala et al. (2012)
Grassland ANPP depends on precipitation in the current year and ANPP in the previous year

$ANPP_t = f(Precip, ANPP_{t-1})$

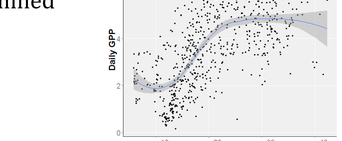
Williams et al. (2011)
Forest Drought-Stress Index depends on cold-season precip and warm season vapor pressure deficit (VPD)

$FDSI = f(Precip_{cold}, VPD_{warm})$

Grassland Hypothesis
$EVI_{max} = f(Precip_{annual}, EVI_{max\_py})$



Forest Hypothesis
$EVI_{max} = f(Precip_{cold}, Tmax_{summer})$



Modeling

Models were fit for all possible combinations of predictors to data for combined forest, shrubland, and grassland sites. The best models were selected based on Akaike's Information Criterion adjusted for small sample sizes (AIC_c) and regression correlation coefficients (r^2).

Production response:

There were 13 annual EVI_{max} values(2001 -2013) for each site.

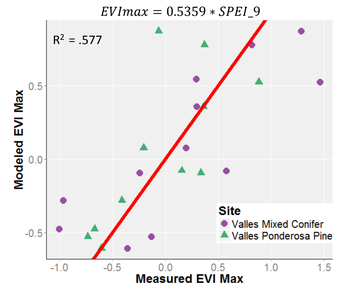
Predictors:

SPEI = Standardized Precipitation Evapotranspiration Index
SPEI was included as a predictor at 1, 2, 3, 6, 9 and 12-month timescales in this analysis.
Additional predictors were T_{max}, VPD, and precipitation (seasonal, annual, and bimonthly averages).

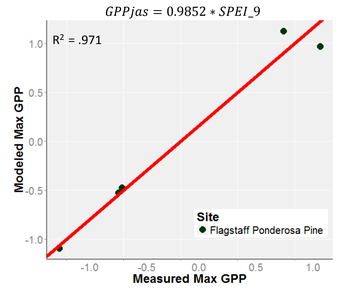
Results

- Forests: Production is best determined by 9-month SPEI (Dec- Aug)
- Remote sensing and flux results agree well

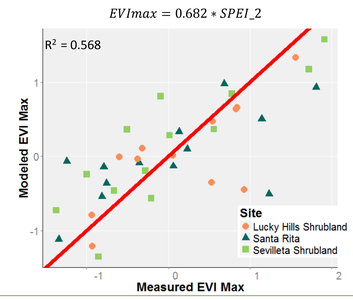
Modeling Results

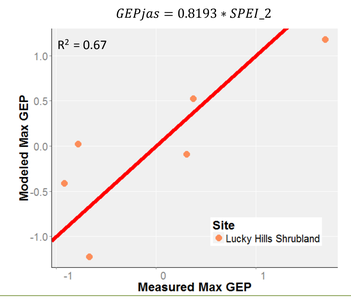


Flux Validation

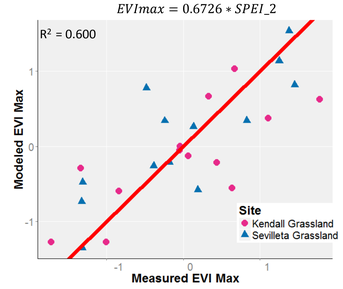


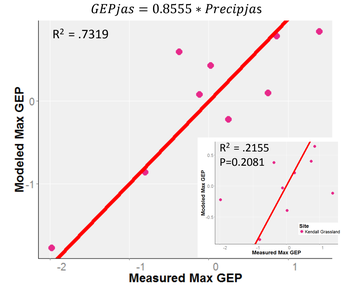
- Shrublands: Production is best determined by 2-month SPEI (July-August)
- Remote sensing and Flux results agree well





- Grasslands: production is determined by 2-month SPEI (July-August)
- Remote sensing and flux do not agree – $SPEI_{2\text{-month}}$ does not significantly predict variation in GEP_{max} (small inset), however precipitation in July –September is well correlated with GEP_{max}

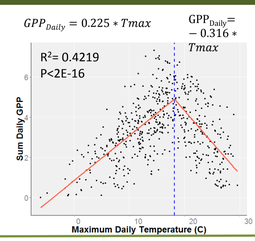




Interpretation and Conclusions

Interpretation of Forest results – Flagstaff Unmanaged Forest

- Piecewise regression reveals a break point in Daily Tmax in May, June, and July
- At temperatures above 18.21° C, daily Tmax is negatively correlated to GPP



- When daily Tmax is above 18.21°C, variation in GPP is largely determined by daily soil moisture (r=0.65)
- This relationship appears to be nonlinear

- The Standardized Precipitation-Evapotranspiration Index (SPEI) was the best predictor of variation in vegetation production across ecosystem types
  - Forests were determined by 9-month SPEI
  - Grasslands and shrublands were both determined by 2-month SPEI
- Agreement between model results and flux data depended on ecosystem type
  - Grassland model and flux data disagreed
  - Good agreement between models and flux data in forests and shrublands
- The coupled approach (remotely sensed observations and *in situ* flux measurements) has the potential to generalize the functional responses of vegetation to predicted future climate conditions.

Eddy covariance flux data sources:
Russell Scott, USDA ARS Southwest Watershed Research Center (Kendall Grassland and Lucky Hills Shrubland)
Thomas Kolb, Northern Arizona University (Flagstaff Unmanaged Forest)